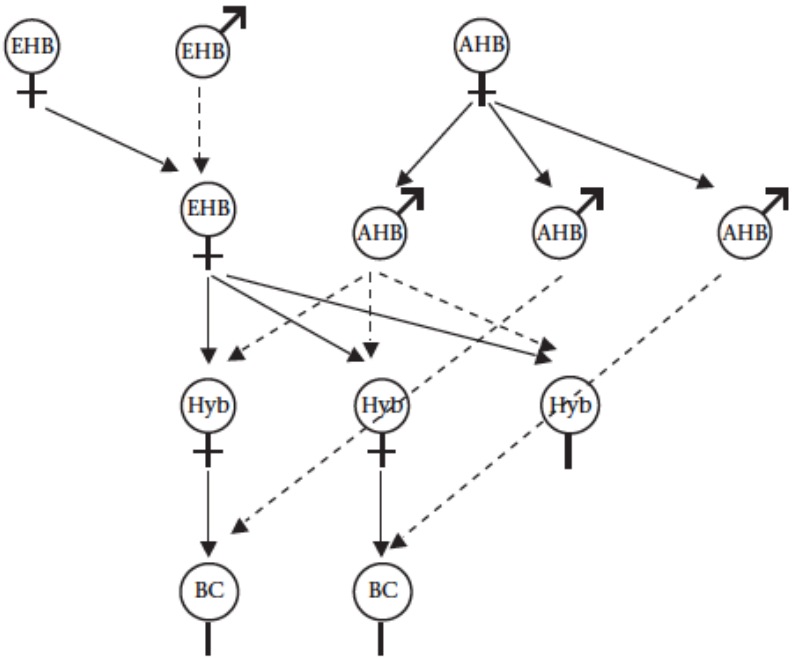
Principles of Bee Breeding

Robert Page
Arizona State University

Why Breed Bees?

- Increase honey production
- Improve overwintering ability
- Decrease defensive behavior
- Reduce swarming
- Reduce or increase use of propolis
- Change color
- Improve queen characters
- Decrease incidence of diseases
- Other personal reasons

Breeding versus Queen Rearing



Most important part of a breeding program

H.H. Laidlaw

Principles of Queen Rearing

- Provide lots of nurse bees
- Provide lots of drones

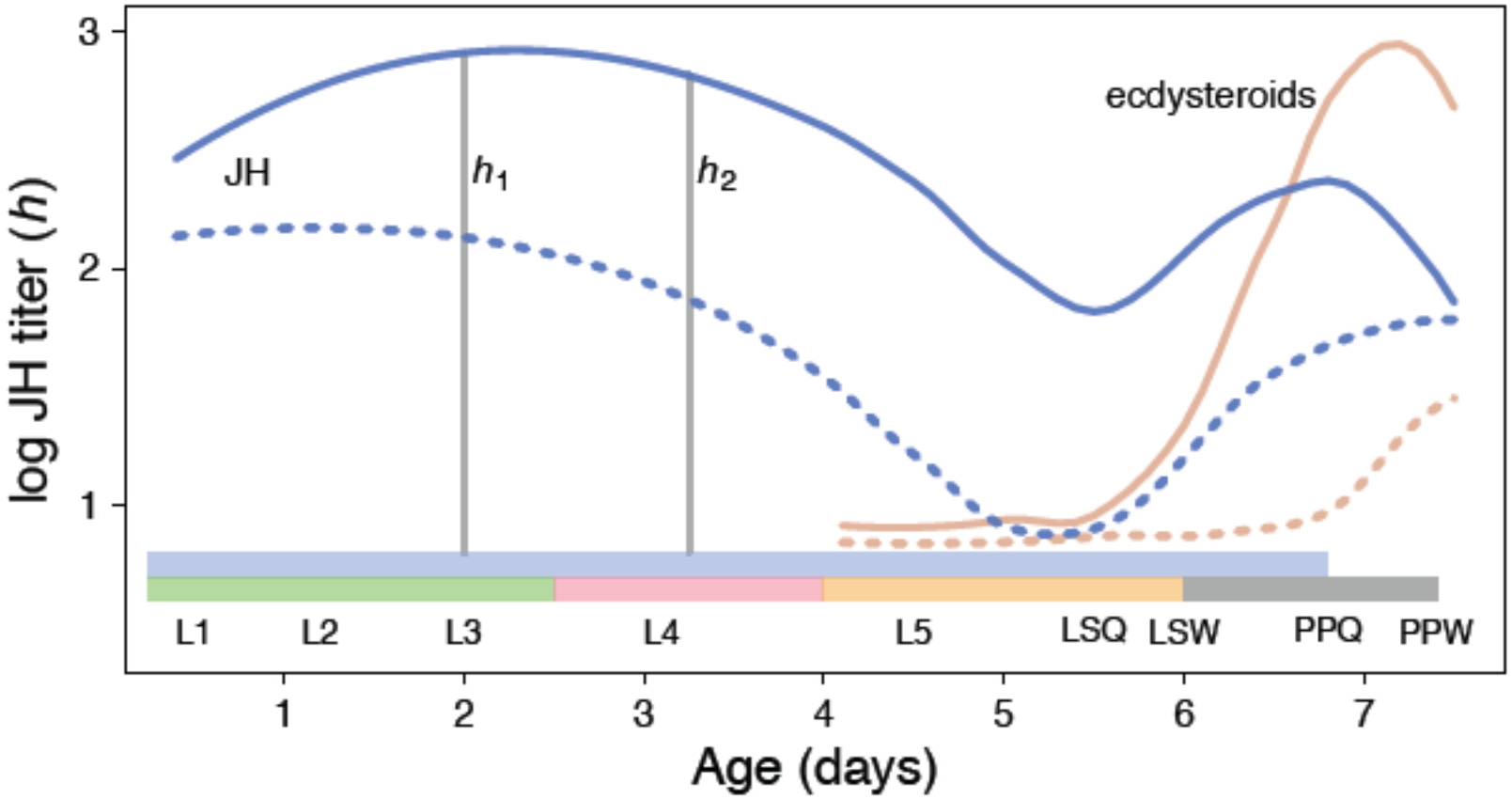
Honey bee gender and caste

Workers

fed low sugar
restrict food
increase sugar
starve

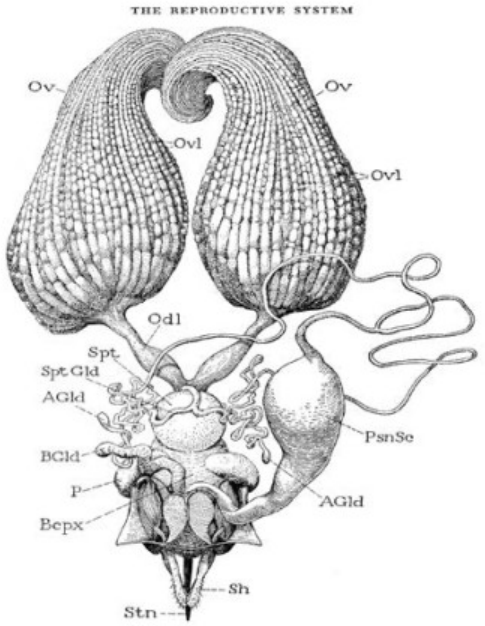
Queens

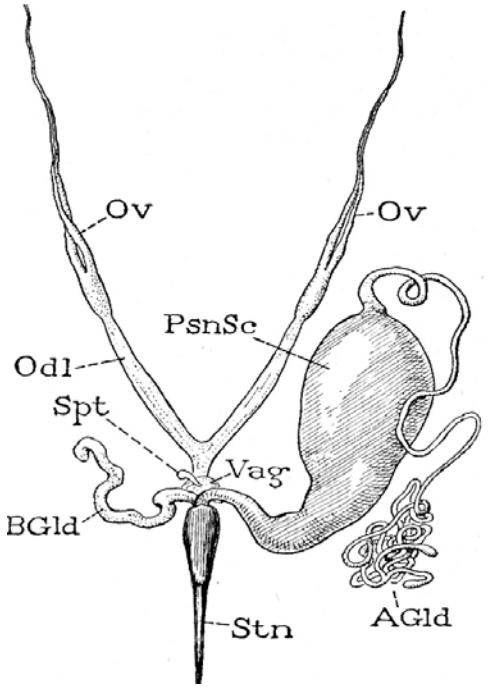
fed high sugar food



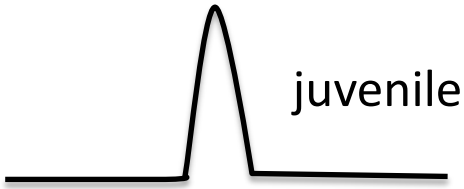
Leimar et al. 2012

Programmed cell death in ovaries





queen

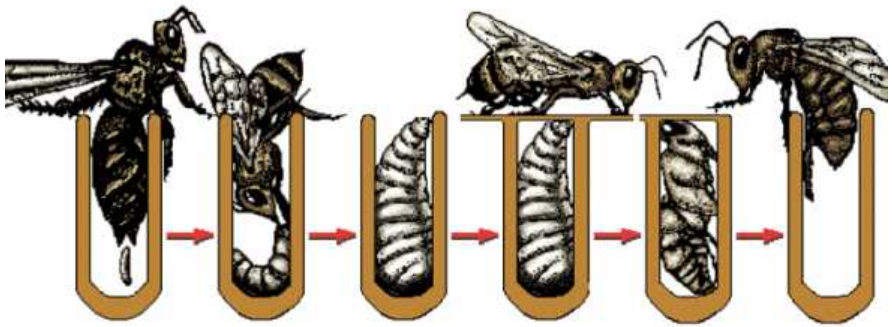


juvenile hormone

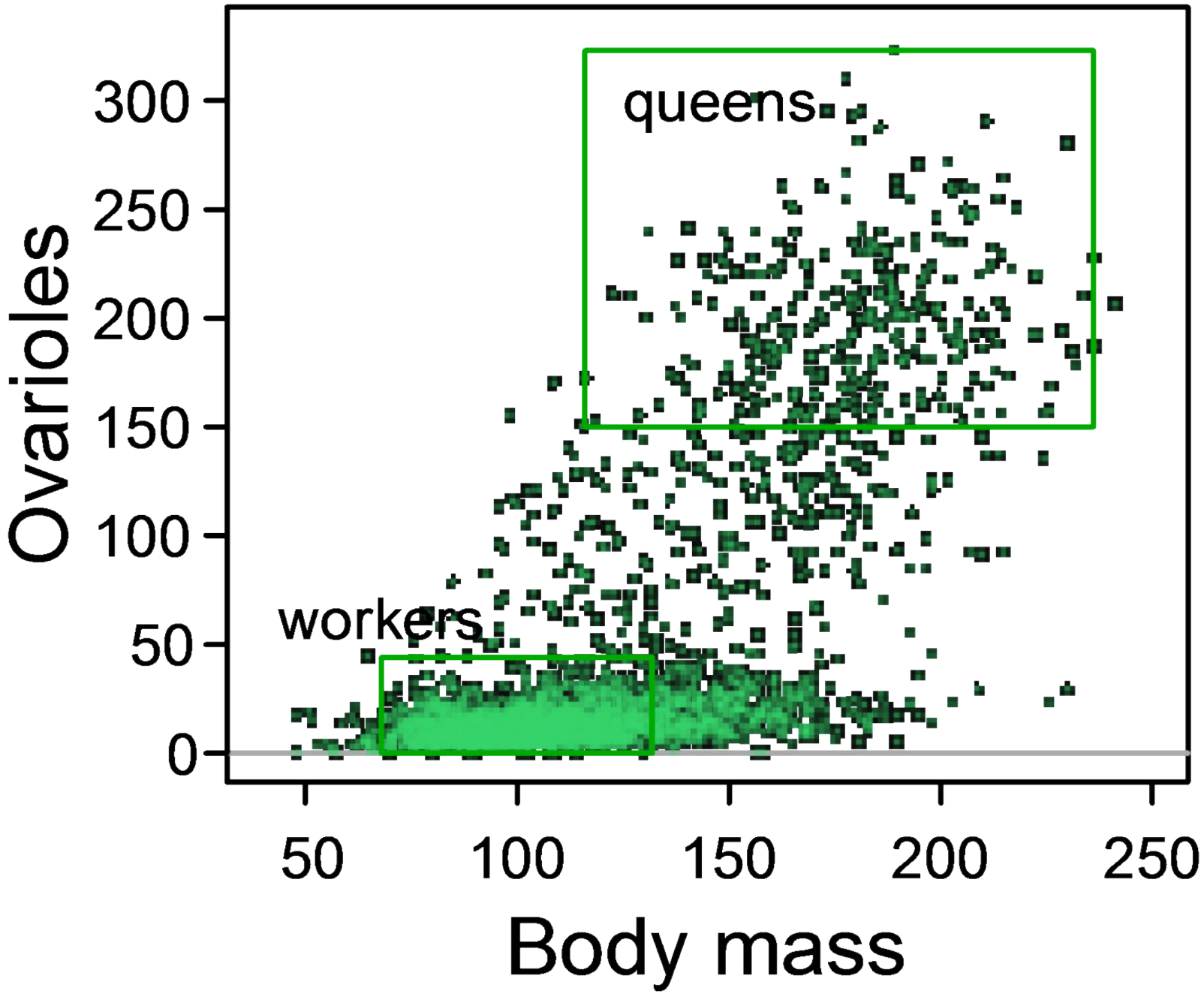
worker

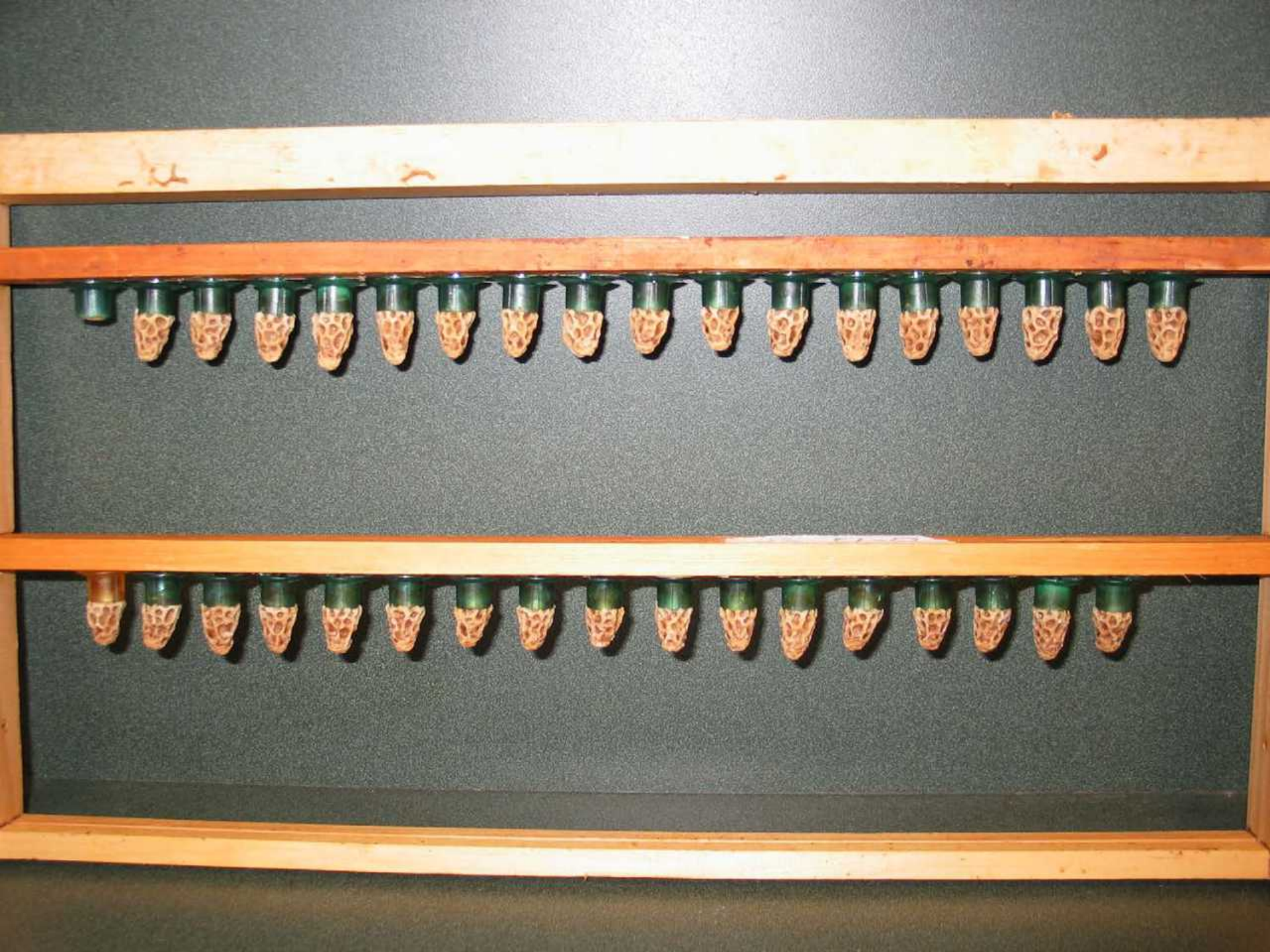
egg L5 pupa

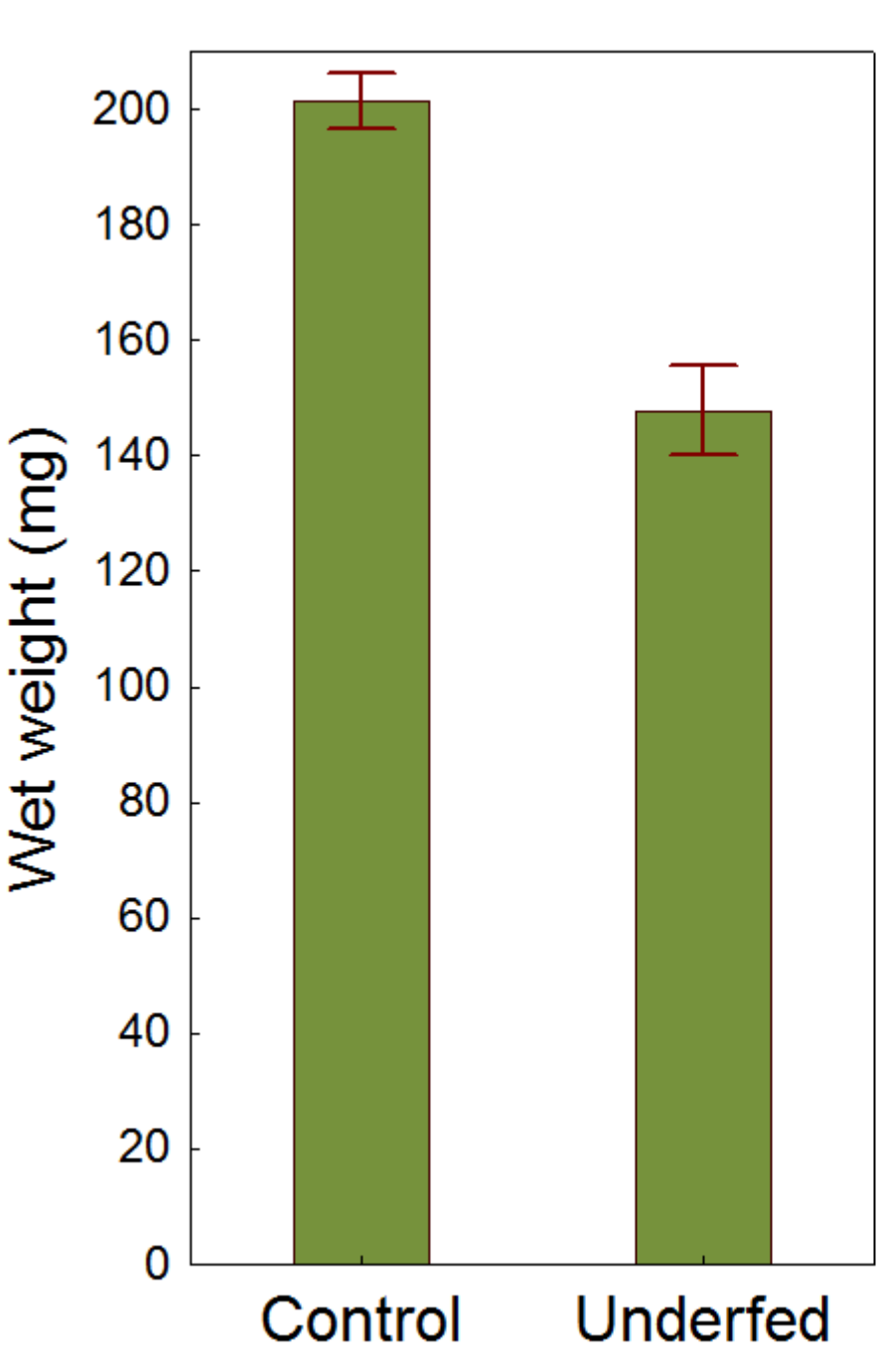
egg L5 pupa

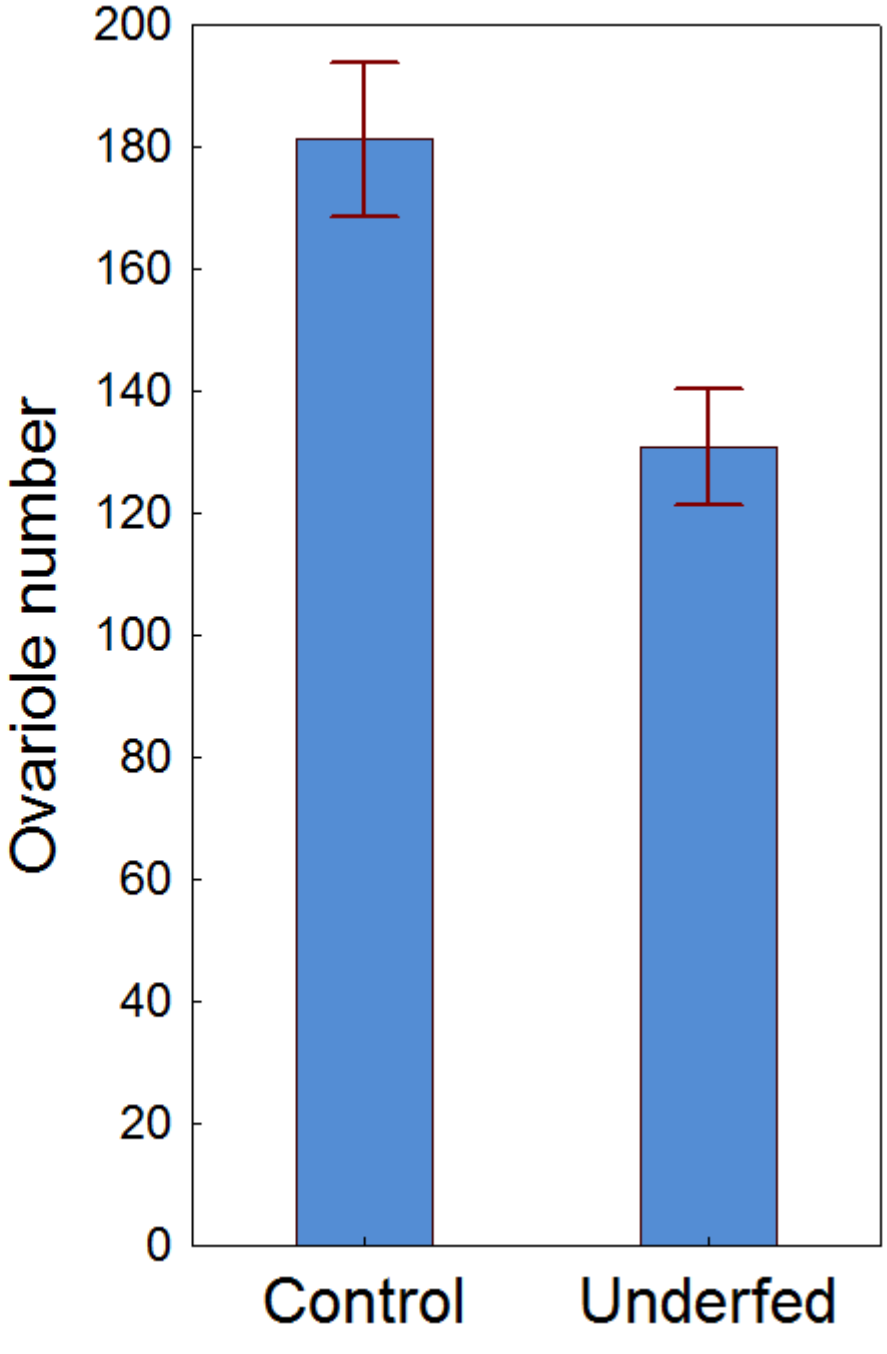


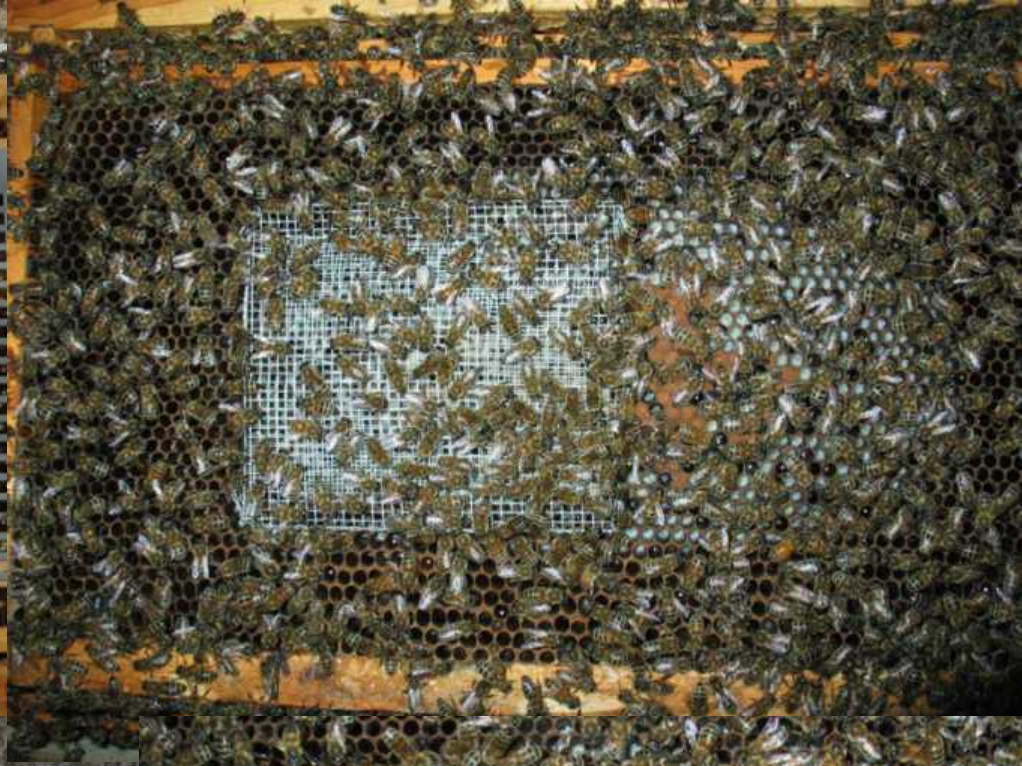
In vitro rearing

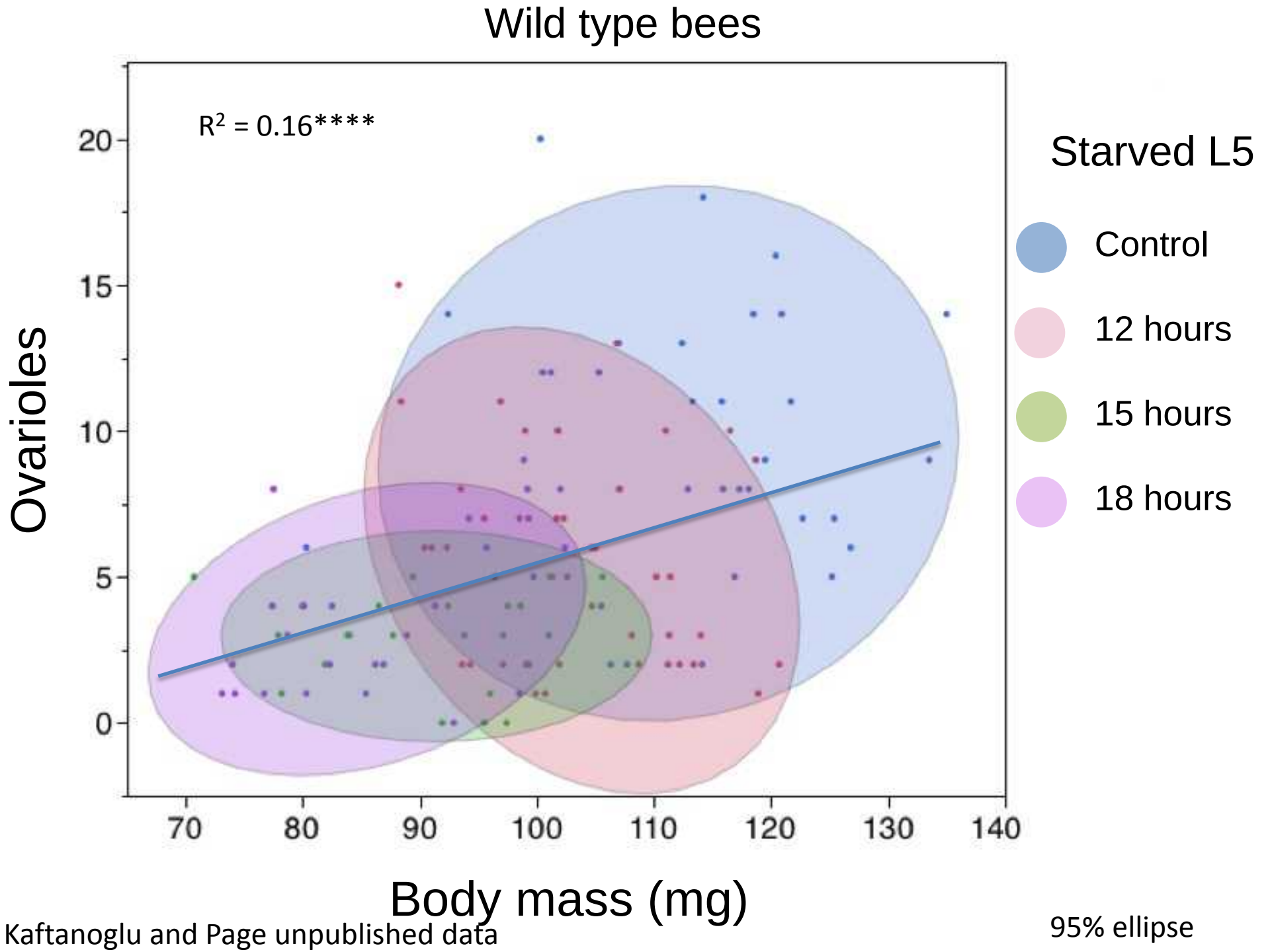

queens
workers
Ovarioles
300
250
200
150
100
50
0
50
100
150
200
250
Body mass




Wet weight (mg)
0
20
40
60
80
100
120
140
160
180
200
Control
Underfed

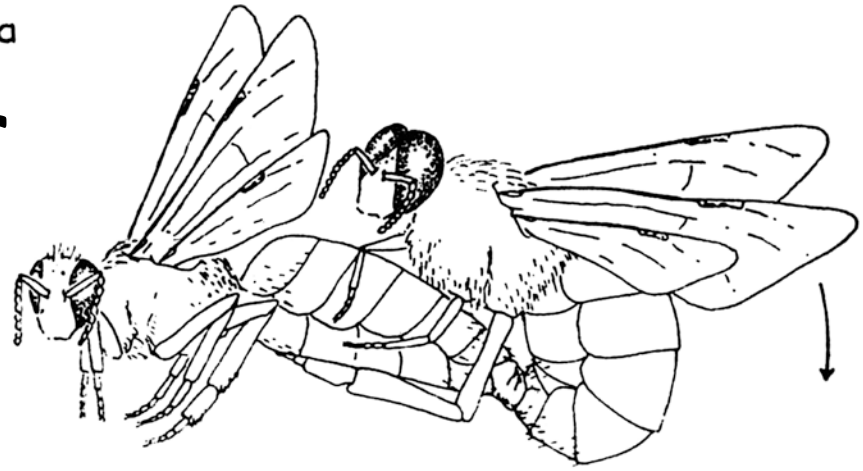

Ovariole number
0
20
40
60
80
100
120
140
160
180
200
Control
Underfed

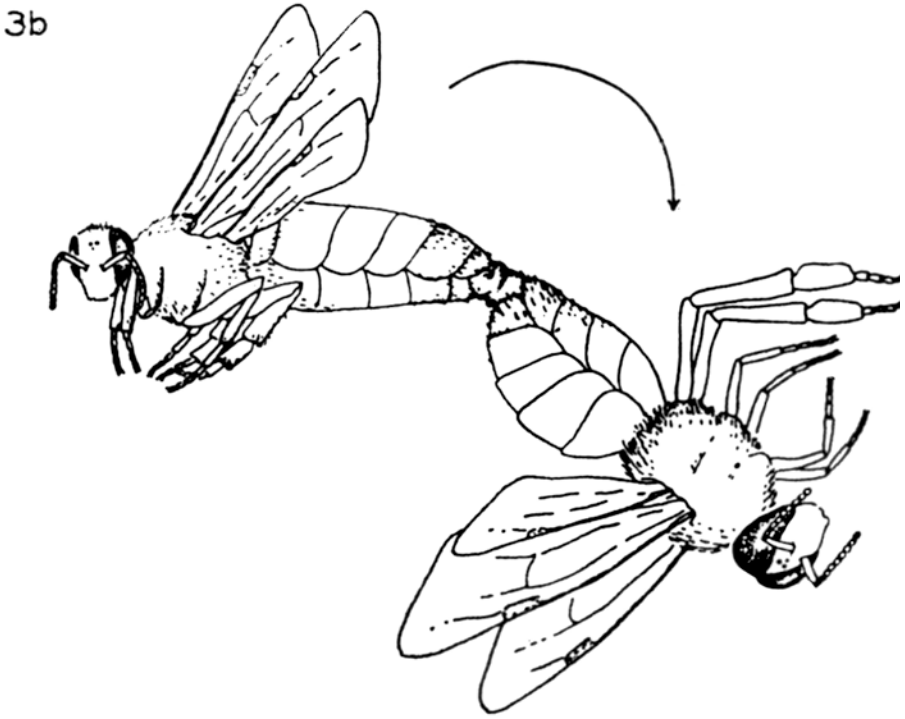


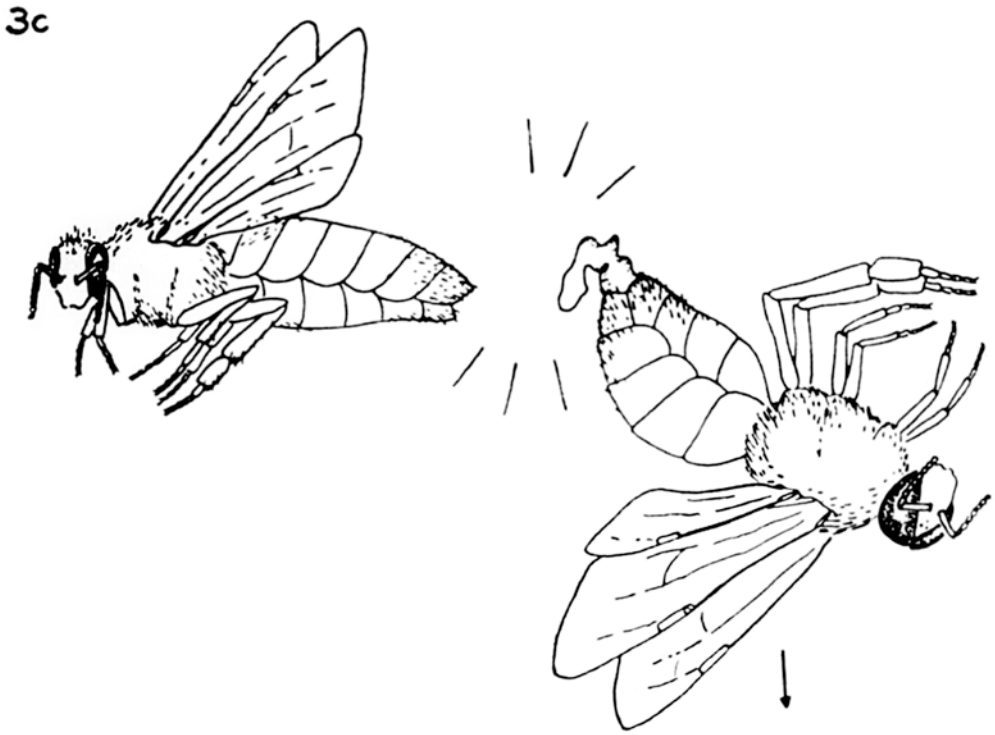

Wild type bees
R^2 = 0.16****
Ovarioles
20
15
10
5
0
70
80
90
100
110
120
130
140
Body mass (mg)
Starved L5
Control
12 hours
15 hours
18 hours
Kaftanoglu and Page unpublished data
95% ellipse

Mating behavior

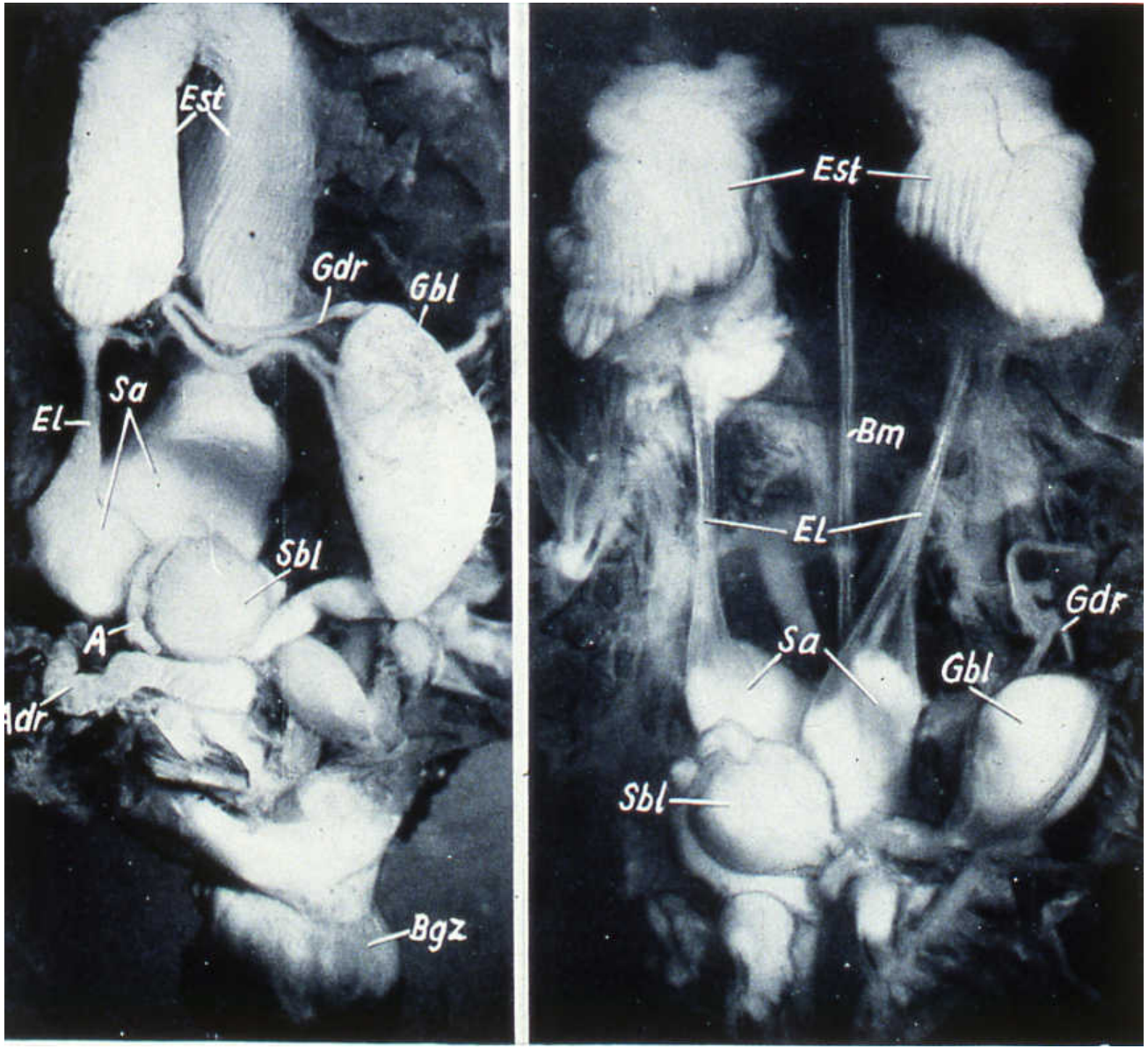
(polyandry)

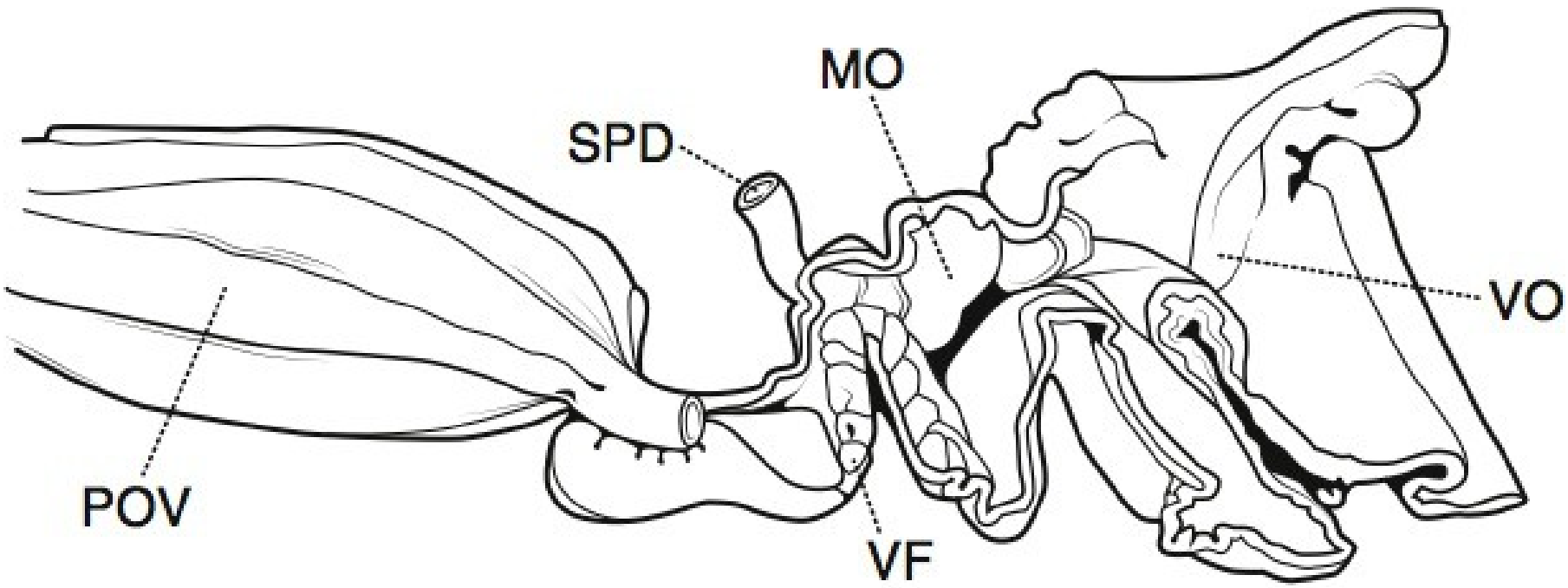




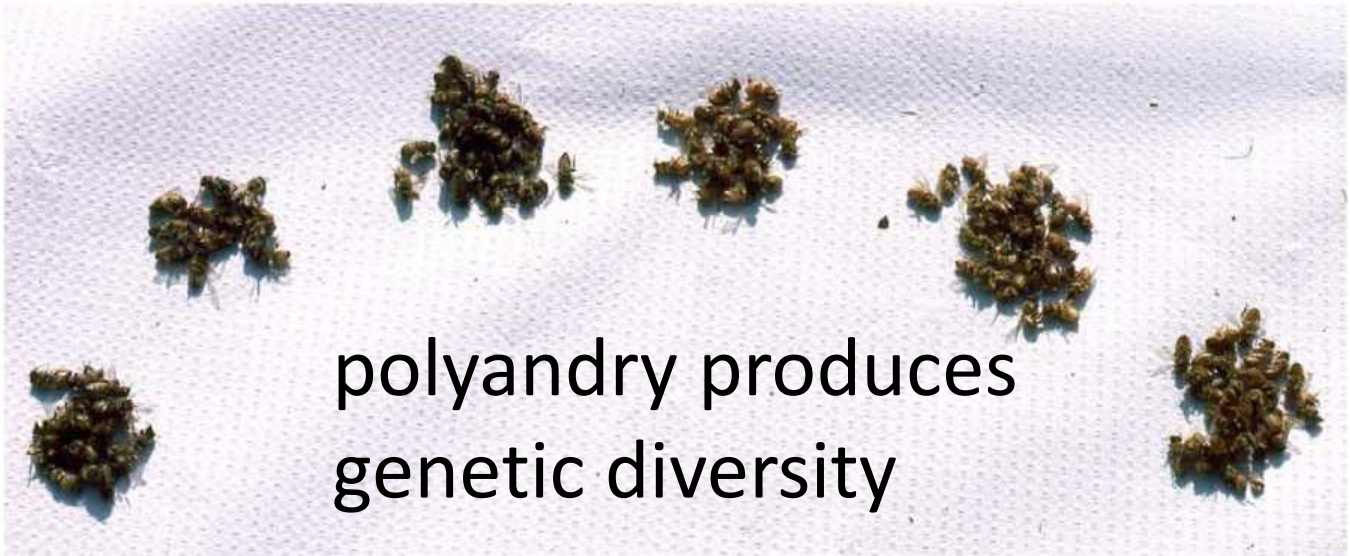


Gudrun Koeniger


Est
Gdr
Gbl
Sa
El
Sbl
A
Adr
Bgz
Est
Bm
EL
Gdr
Sa
Gbl
Sbl


MO
SPD
VO
POV
VF

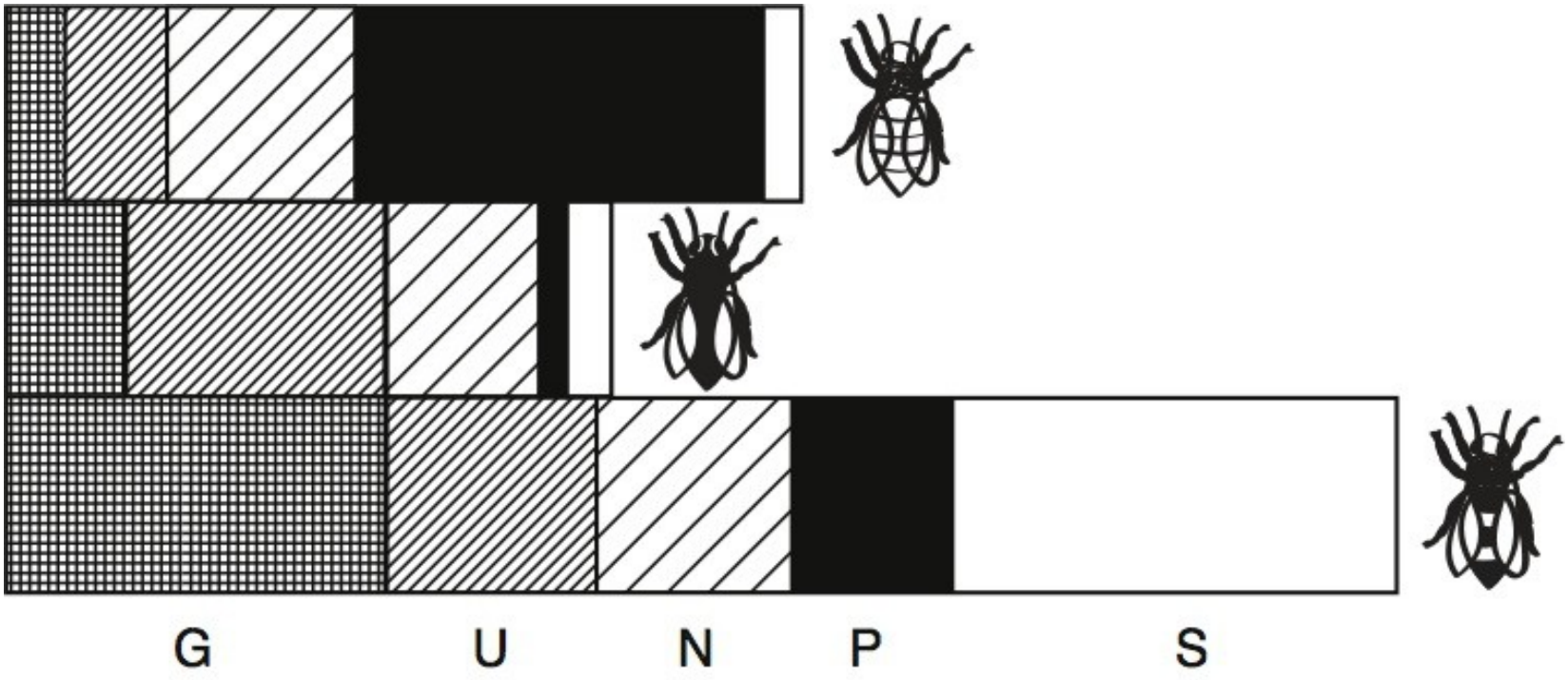
♀ X

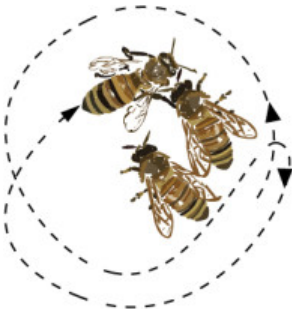


polyandry produces genetic diversity

Division of labor

Genetic diversity affects division of labor





Genetic diversity is important:

- fly > 5 km to avoid inbreeding
- mate with large number of males
- have mechanisms to insure sperm mixing
- have highest recombination rate (20X humans)
- affects distribution of thresholds and division of labor

Early Breeding

- Mendel tried to select better bees
- He could not control matings
- Not until 1940's could we control matings with development of II

Fundamental Principle of Breeding

Offspring resemble their parents

(requires genetic variation)

Genetic Variation

- Colony level
- Individual level

Genetic variation for colony traits

- Number of workers
- Worker comb
- Drone comb
- Total brood
- Propolis
- Undertaking
- Stored pollen
- Hygienic behavior
- Sugar solution storage
- Tracheal mite resistance

Individual Genetic Variation

Retinue behavior
Fanning
Nectar load size
Pollen load size
Concentration of nectar
Water foraging
Food sharing
Guarding
Scouting food
Scouting nest sites
Pollen dance attendance
Light sensitivity
Walking activity
Life span
Age of foraging
Grooming
Ovary size
Stinging
Sensitivity to sugar
Learning
Dancing for pollen
Response to brood
Response to stored pollen
Undertaking
Body color
Queen development
Nursing behavior
Body weight
Others….

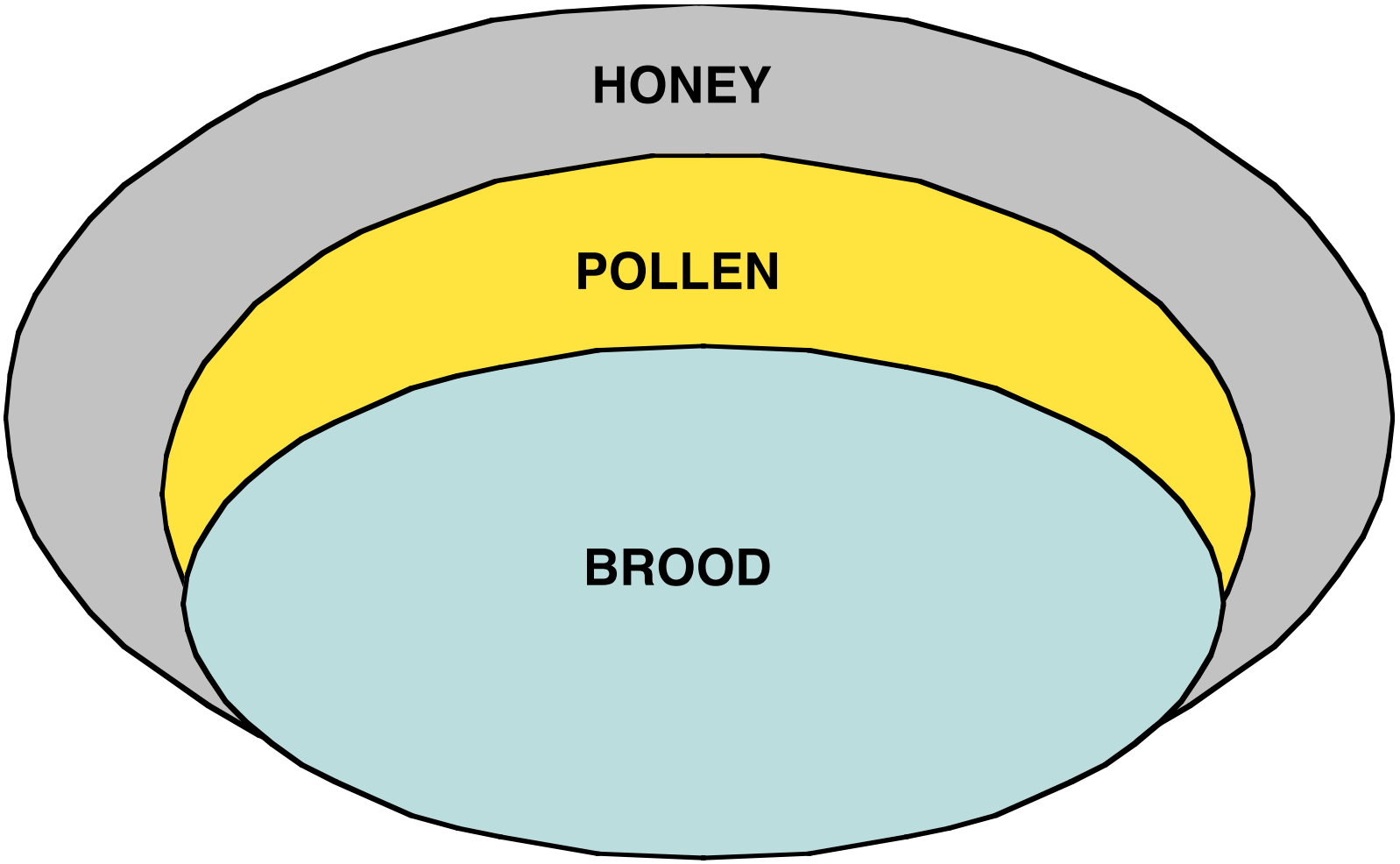
Mechanism of Breeding

- Select parents based on some trait
- Raise queens and drones
- Control mating

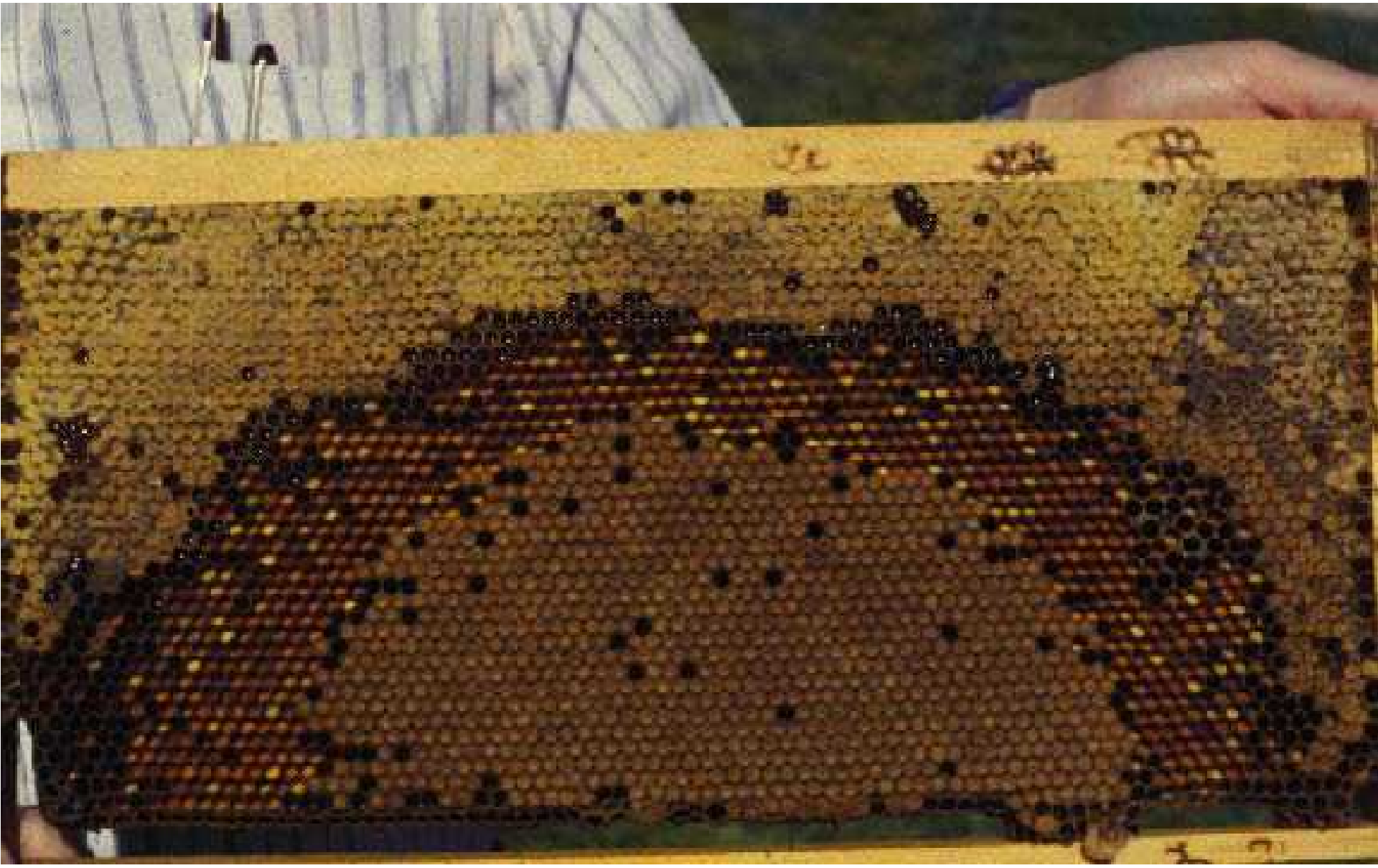
Steps in Breeding

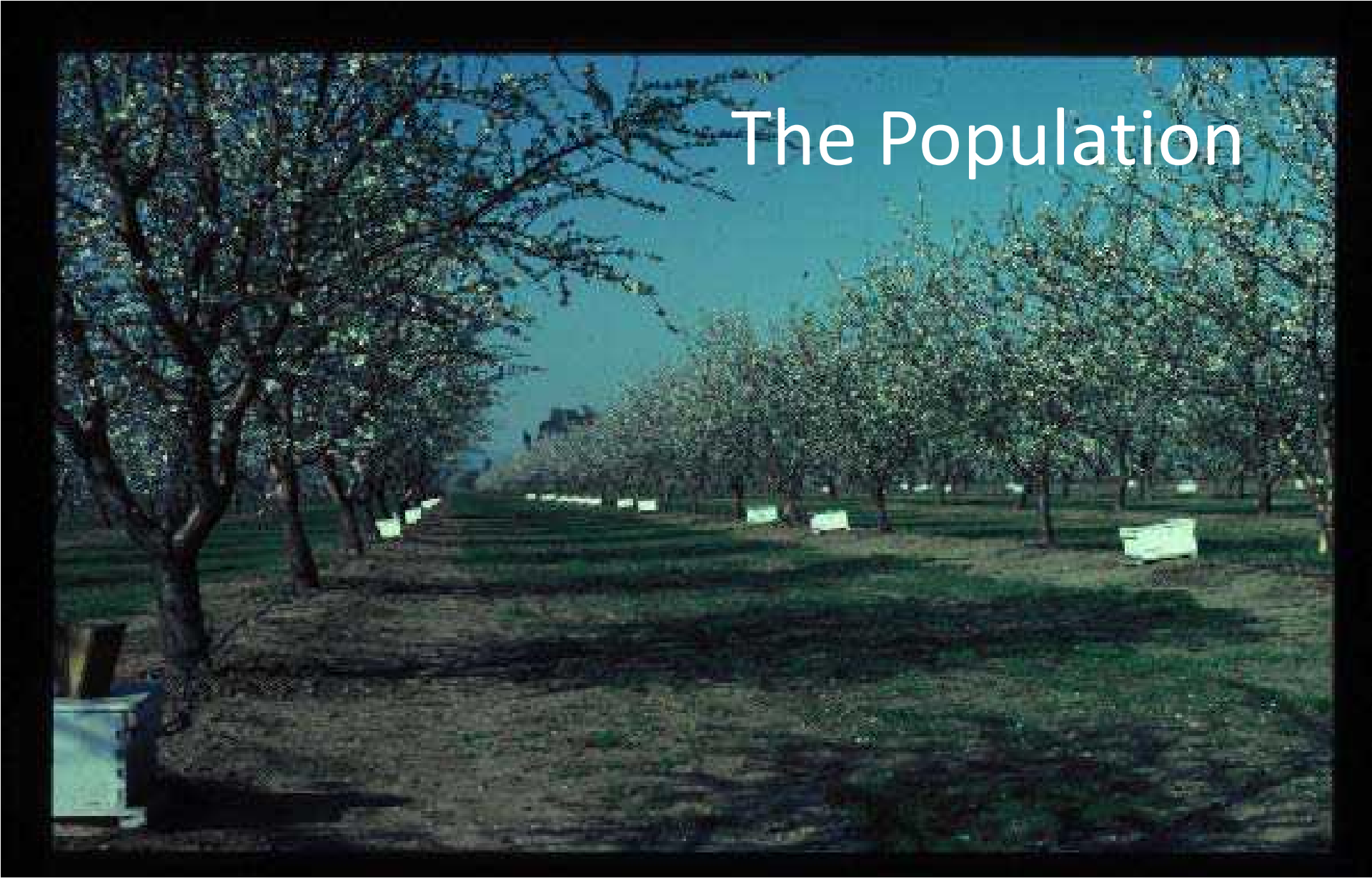
- Decide on a trait (phenotype)
- Develop an assay
- Measure the foundation population
- Select parents
- Control mating using a design
- Evaluate, document, and verify
- Select parents

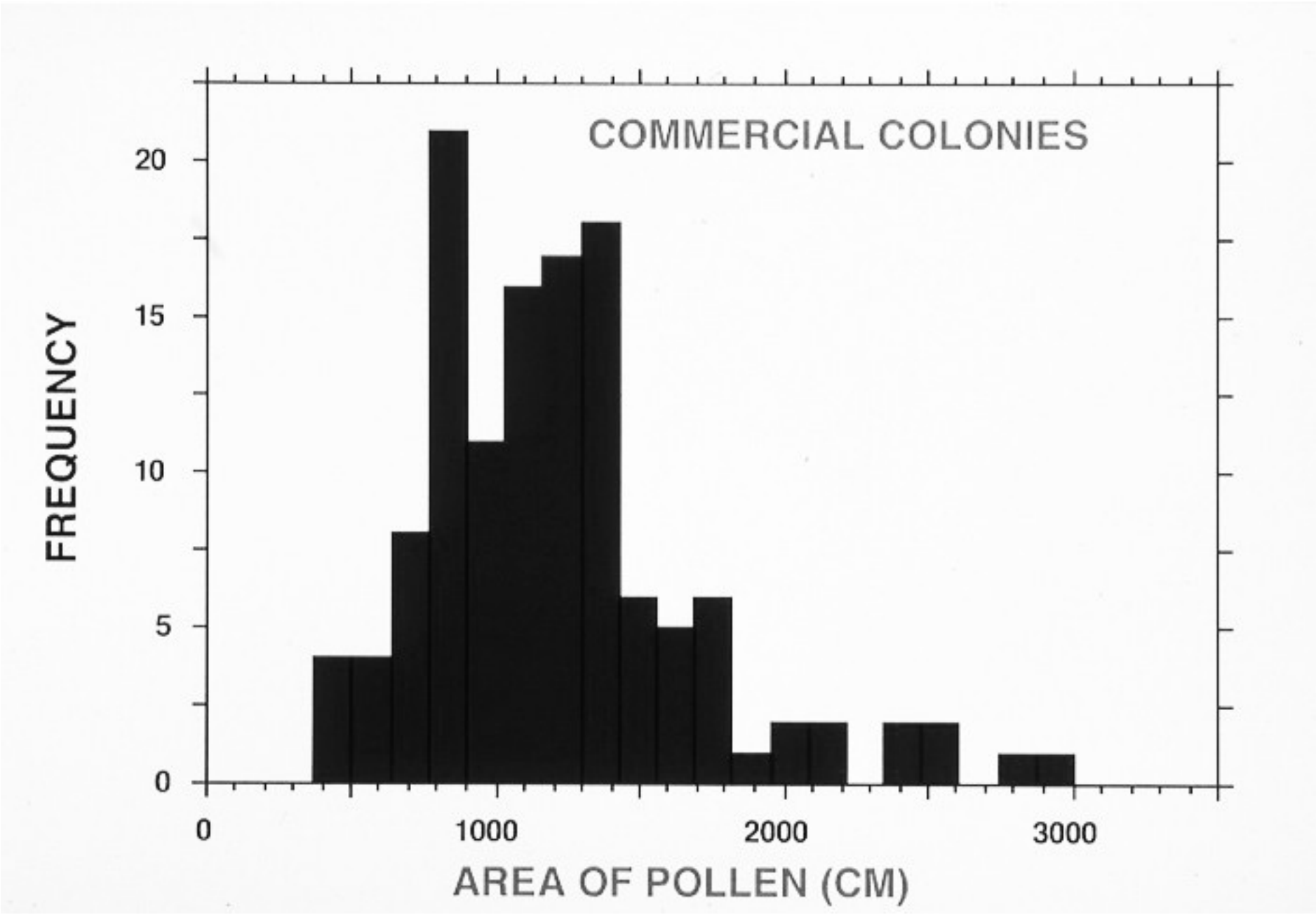
The Phenotype



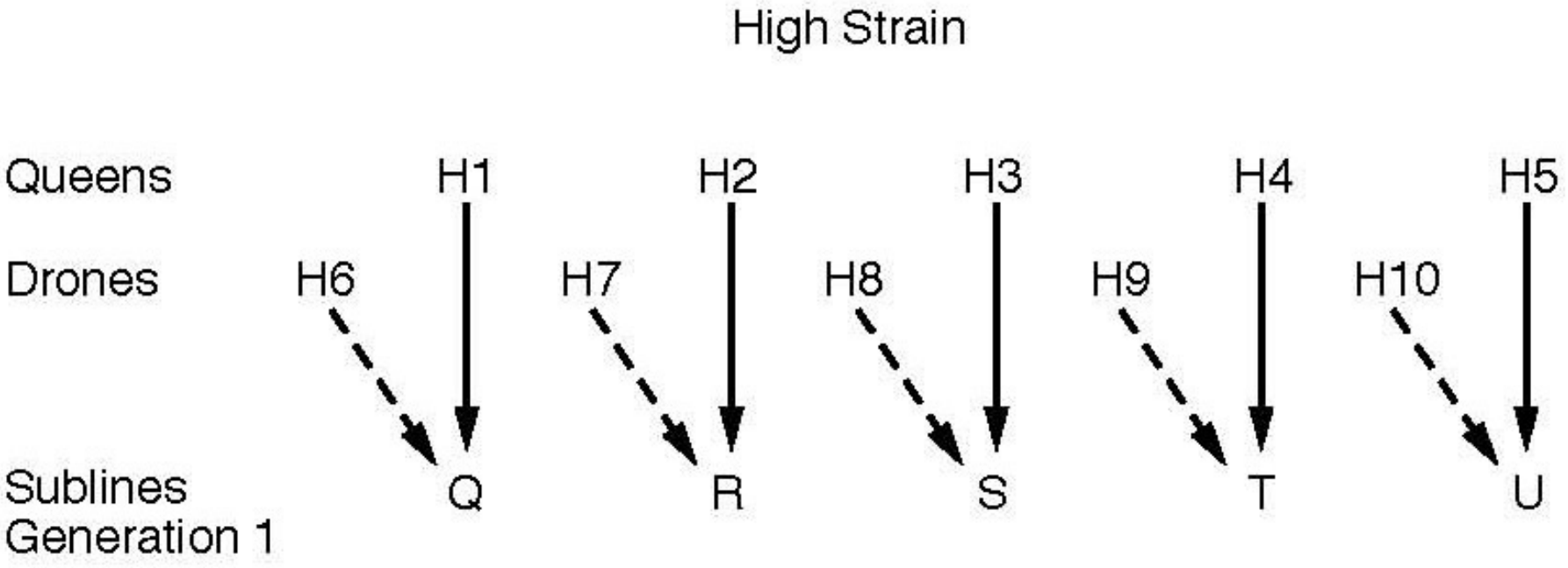
The Assay




The Population


COMMERCIAL COLONIES
FREQUENCY
20
15
10
5
0
0
1000
2000
3000
AREA OF POLLEN (CM)

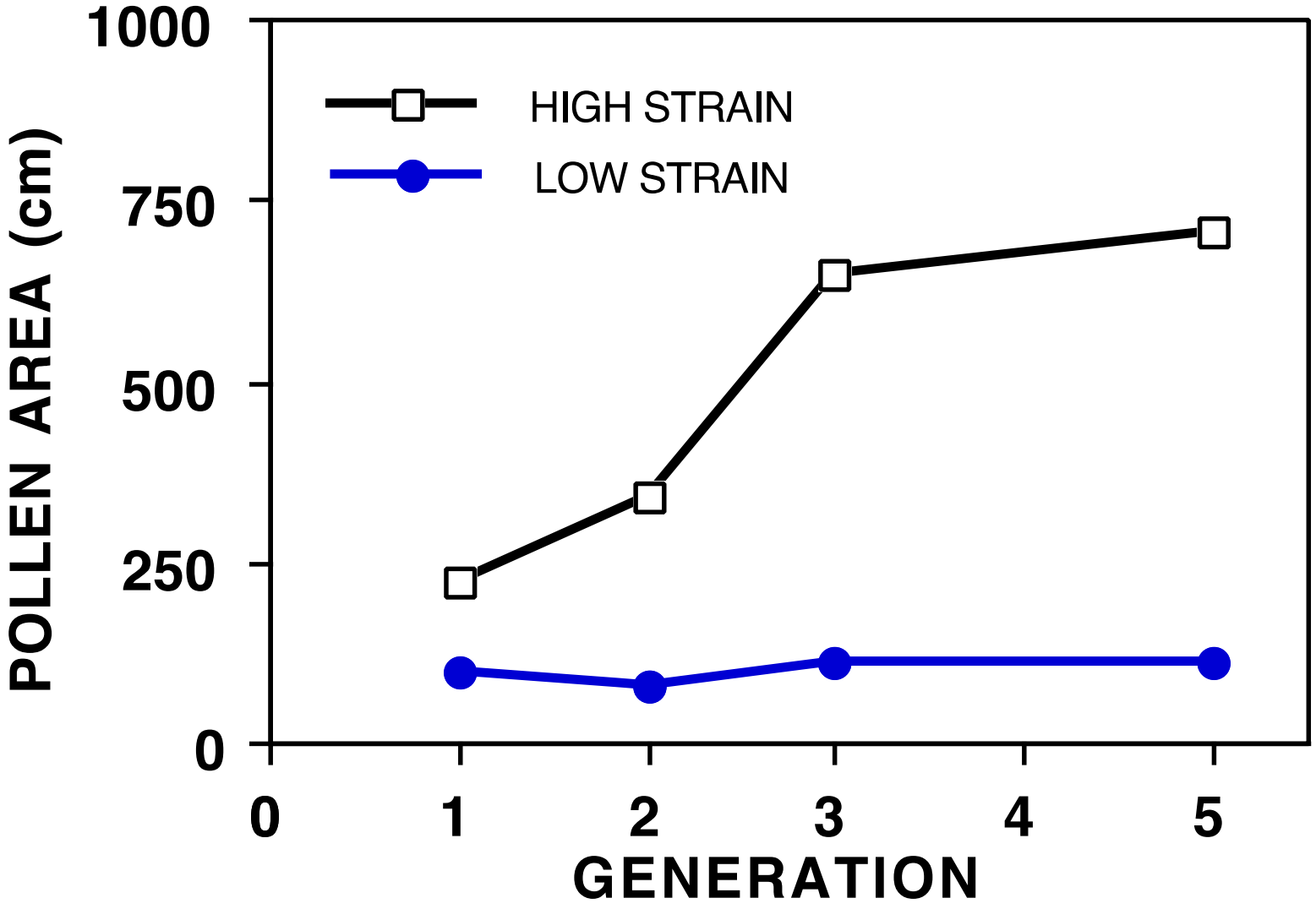
Mating Design



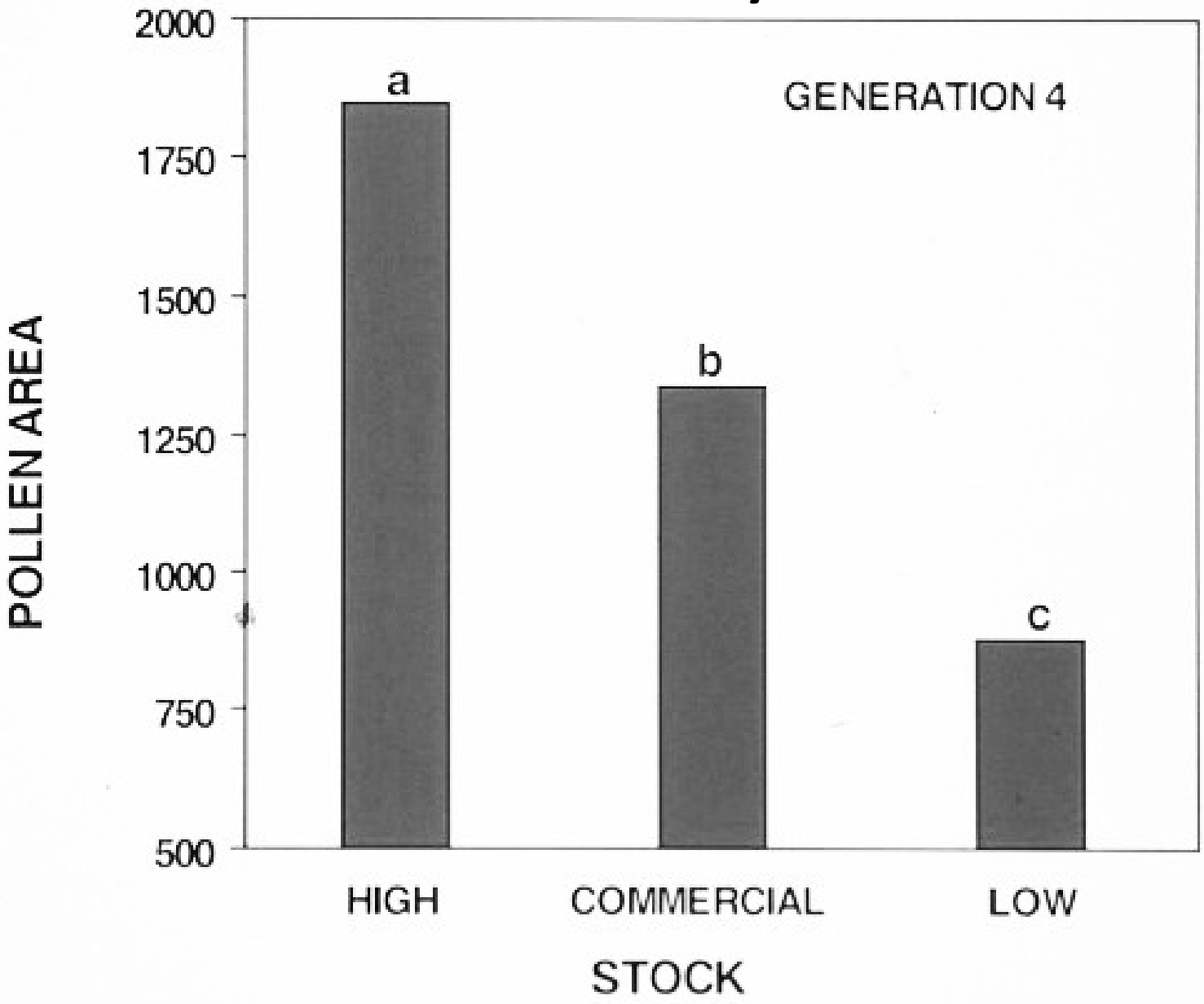
Mating Control

Evaluate

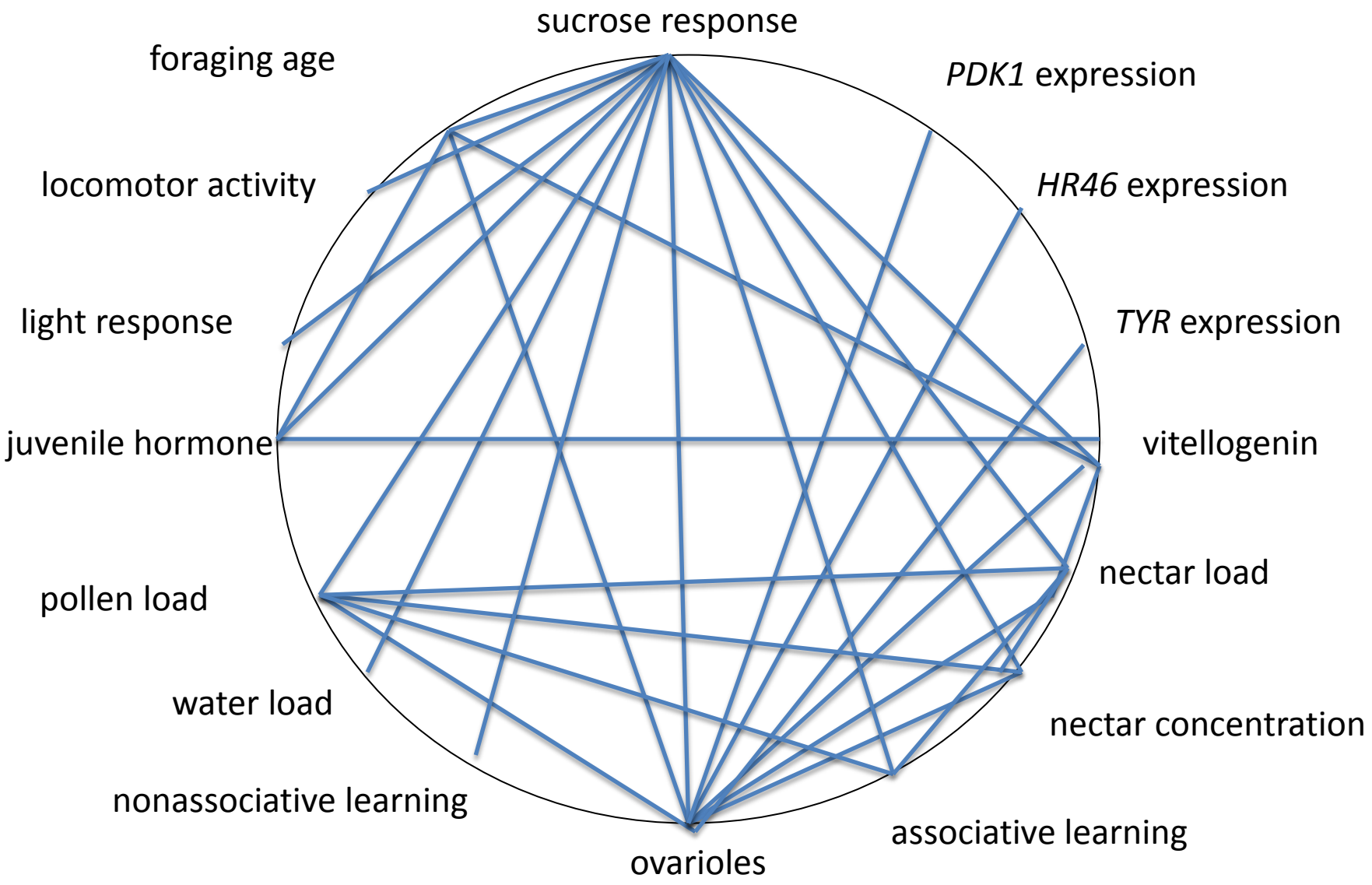
Document

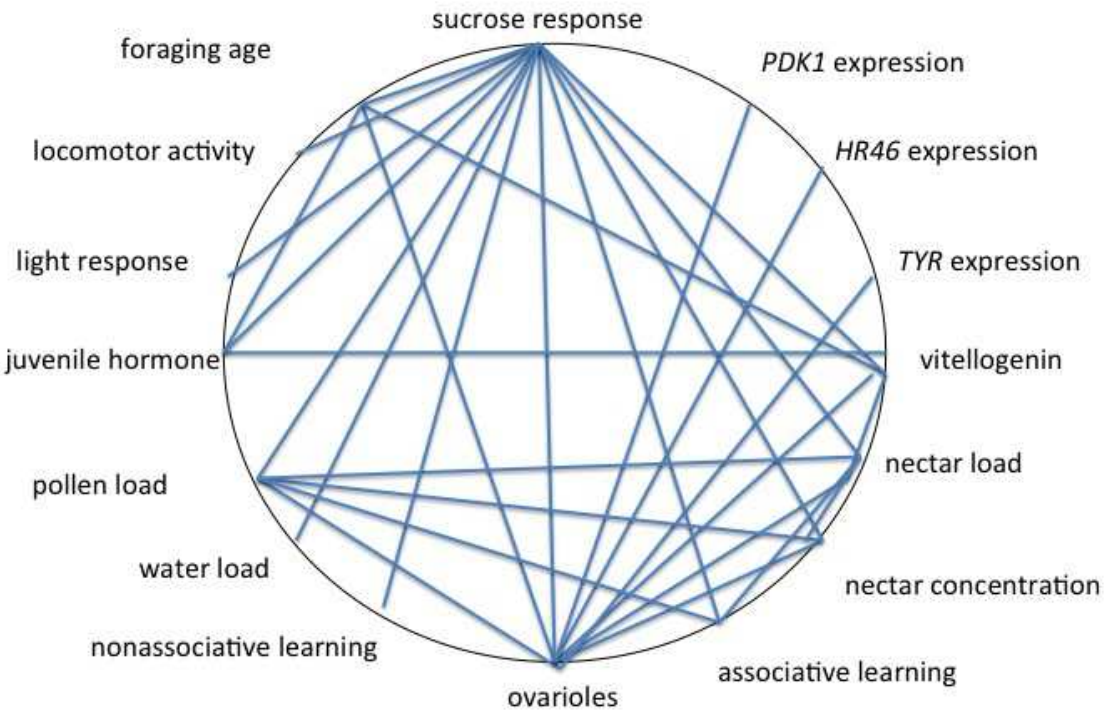

1000
750
500
250
0
POLLEN AREA (cm)
HIGH STRAIN
LOW STRAIN
0
1
2
3
4
5
GENERATION

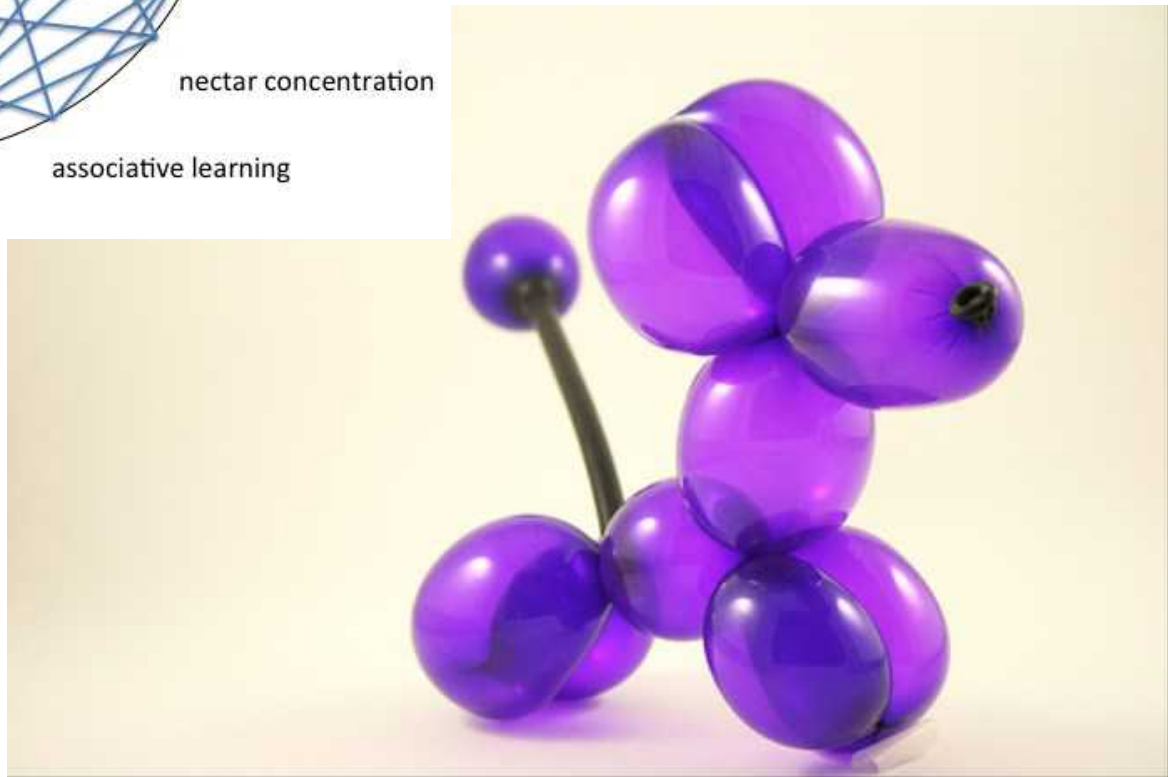
Verify

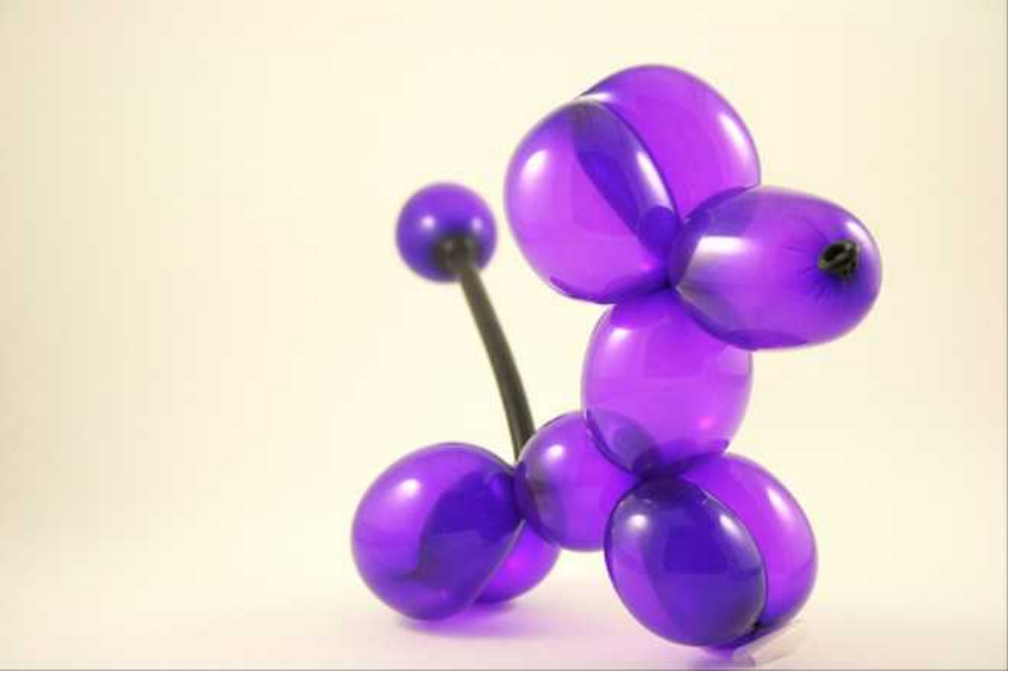

GENERATION 4
POLLEN AREA
2000
1750
1500
1250
1000
750
500
a
b
c
HIGH
COMMERCIAL
LOW
STOCK

Correlated Characters




sucrose response
foraging age
PDK1 expression
locomotor activity
HR46 expression
light response
TYR expression
juvenile hormone
vitellogenin
pollen load
nectar load
water load
nectar concentration
nonassociative learning
associative learning
ovarioles





With Selection

Without Selection

School of Life Sciences
Arizona State University
Honey Bee Research Lab